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(54) BATTERY EQUALIZER

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(12) (19) (CA) **Demande-Application**

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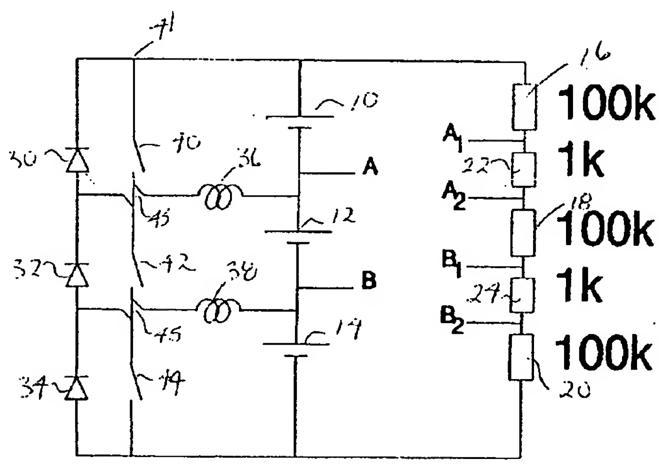
(54) **BATTERY EQUALIZER**

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**BATTERY EQUALIZER**

## BACKGROUND OF THE INVENTION

This invention relates to equalizers for equalizing charging of a plurality of cells or batteries such that the charging is equalized, and to devices for improving the charging of a single cell or battery.

It is conventional to charge a plurality of cells or batteries, usually in series, at the same time. A current is applied to the plurality of batteries and they are charged together for the same amount of time. However these cells or batteries may be in different conditions and may have been in different states of discharge at the time the recharging is commenced. It would be desirable to provide some device for improving the charging procedure such that the batteries or cells are charged equally or so that the charging is individualized for each of the cells or batteries being charged at the same time. It would also be desirable to provide a device which improves the charging of a single cell or battery compared with the type of charging obtained by applying an even current for a certain period of time.

## SUMMARY OF THE INVENTION

There is provided according to the invention a device which monitors the charging of a series of individual cells or batteries and which alters the charging of each cell or battery depending upon its particular condition.

In particular, the device monitors the electrical potential between different cells or batteries. If the difference in potential is greater than a certain amount, then the cell or battery with the highest voltage is discharged and the charge is diverted to a cell or battery with a lower potential.

## BRIEF DESCRIPTION OF THE DRAWINGS

Fig. 1 is a simplified schematic diagram of a battery equalization device according to an embodiment of the invention, used for three batteries;

Fig. 2 is a diagram similar to Fig. 1 of a variation used for four batteries and using coupled inductors;

Fig. 3 is a schematic diagram similar to Fig. 2 wherein the device uses coupled inductors with two sets of windings;

Fig. 4 is a pulsing circuit according to an embodiment of the invention for use with a single cell or battery;

Fig. 5 is a detailed circuit diagram of the embodiment of Fig. 1; and

Fig.. 6 is a graph showing voltages of three batteries over a period of time when charged with the device of Fig. 1.

## DETAILED DESCRIPTION OF THE PREFERRED EMBODIMENTS

Referring to Fig. 1, this shows in simplified form an equalizer circuit for charging three batteries or cells 10, 12 and 14. The circuit includes two sets of carefully matched resistors including three 100k resistors 16, 18 and 20 and two 1k resistors 22 and 24. The resistance of these sets of resistors is dictated by such factors as the voltage of the cells or batteries being charged. The resistors are connected together in series as shown in Fig. 1 and the set of resistors is connected parallel to the batteries 10, 12 and 14.

The resistance ratio of the resistors is assumed constant as ideally are the resistors

themselves. The string of resistors provides voltage references as equal percentages of the total voltage of the series battery string, in this case one third and two thirds nominal with thresholds of roughly 0.5% above and below these values provided by the 1k resistors. If the batteries are identical, the voltages across one of the batteries will be between the threshold voltages determined by the resistor string and the equalizer circuit will do nothing. This is true whatever the total battery voltage may be . This total is a function of factors such as whether the batteries are being charged or discharged.

There is also a set of three diodes 30, 32 and 34 connected together in series with the set connected in parallel to the batteries and the set of resistors. There are two inductors 36 and 38. Inductor 36 has one terminal connected between the batteries 10 and 12 and the other terminal is connected between diodes 30 and 32. The other inductor 38 has one terminal connected between batteries 12 and 14 and the other terminal connected between diodes 32 and 34.

The device also has three switches 40, 42 and 44. Switch 40 has one terminal connected to a junction 41 between a first terminal of diode 30 and battery 10 while the other terminal is connected to junction 43 between inductor 36 and a second terminal of diode 30 and a first side of diode 32. Switch 42 has one terminal connected to junction 43. The other terminal of switch 42 is connected to junction 45 between inductor 38 and a second terminal of diode 32. Switch 44 has one terminal connected to junction 45. The other terminal of switch 44 is connected between a second terminal of diode 34 and battery 14.

The device operates by monitoring the voltages at nodes A and B which are located between batteries 10 and 12 and batteries 12 and 14 respectively. The resistors 16-24 operate to generate reference voltages by dividing the voltage across the battery string.

The device monitors the voltage at nodes A and B and compares them to voltages at A1 and A2 and voltages at B1 and B2, respectively. The key is finding which battery has a voltage

which is too high. If, for example, voltage A is between the voltages A1 and A2, then nothing happens. If, however, voltage A is less than voltage A2, then switch 40 closes. If voltage B is greater than voltage B1 then switch 44 closes to move charge from battery 14 to battery 12. If voltage A is greater than A1 and B is less than B2 then switch 42 closes. The switch is closed for a time depending of the inductance of inductors 36 and 38 and the desired peak current.

When switch 40 is closed, energy from battery 10 is stored in inductor 36. When switch 40 is opened that energy is transferred to batteries 12 and 14 as diodes 32 and 34 conduct. A similar process occurs for switch 44, inductor 38 and battery 14 with energy going to batteries 10 and 12 via diodes 30 and 32.

When switch 42 is closed energy from battery 12 is stored in inductors 36 and 38. When switch 42 is opened the energy from inductor 36 goes to battery 10 via diode 30 and the energy from inductor 38 goes to battery 14 via diode 34.

Thus if battery 10 is low and battery 14 is high, all the energy is not transferred directly from battery 14 to battery 10. Some of it will be stored in battery 12 as an intermediate step.

Alternative types of logic control are possible. For example switch 42 could close when $A>A1$ and $B<B1$ or when $A>A2$ and $B<B2$. This requires more logic but provides a narrower voltage range for the middle battery. The system above operates when a battery is identified as comparatively strong. As a further alternative the system could look for the battery with the weak charge and ensure that it receives charge from the others. For example, if the battery 10 is weak, the previous system would probably take charge from the battery 14 only. The charge would be transferred to the battery 10 as needed, but also to the battery 12 where it would not. A control which identified the weak battery could switch all the other switches equally rather than waiting for a measurable difference between the strong batteries.

Fig. 1 represents a considerably simplified schematic. Fig. 5 is detailed circuit diagram of the embodiment of Fig. 1. The three batteries 10, 12 and 14 are shown along with the resistors 16, 18, 20, 22 and 24. Also shown are the two inductors 36 and 38 along with the nodes A and B between the sets of batteries and the nodes A1, A2, B1 and B2 between the resistors.

Three FET's 50, 51 and 52 combine the functions of switches 40, 42 and 44 and the diodes 30, 32 and 34. The FETs have internal diodes and are functionally equivalent to a switch and parallel diode. For example diode 30 and switch 40 are implemented by using FET 50. There are four comparators. The comparator 70 compares voltage A to A1. Comparator 71 below it compares A to A2. Comparator 73 compares B to B1. Comparator 75 compares B to B2. If the batteries are normal all the comparator outputs will be low. The exact states of the comparator outputs depend on which battery or batteries are low and by how much.

The transistors and latch at the comparator outputs are necessary since it is the steady state comparator output which is of interest. As soon as a switch operates, the corresponding battery voltage will drop to the internal resistance of the battery. Without the latch other switches might operate as a consequence.

Provision is made to ensure that all switches are closed simultaneously to avoid short circuits through all switches in series. The control of the switches is decided by the battery voltages when all the switches are open. As soon as a switch is closed the battery terminal voltage will change due to current flowing through the internal battery impedance. This could lead to random closing of inappropriate switches. The outputs of the comparators 70, 71, 73 and 75 are latched when all switches are open and decoded by the logic gates shown.

Any switch is on for a limited time to ensure that the inductor currents are limited. The pulse width applied to the switches is controlled by the timer shown at bottom right. There is provision via the switch to turn off the pulses completely.

Provision is made for the fact that the individual switches are transistors referenced to different voltages. Various standard isolated driver circuits are suitable. In this circuit n-channel FETs were used for the bottom two switches and a p-channel FET for the top one. This allows for good switching of the top and bottom devices since they are referenced to the ends of the battery which is used as the power supply. The pulse for the middle switch has a return path via inductor 38 and possibly the recovery current of diode 14. However the circuit would work with n-channel devices used throughout with isolated drivers mentioned used for each.

Referring Fig. 2, this shows a modified device 80 for charging four batteries or cells 81, 83, 85 and 87 shown at the bottom of the diagram. The arrangement is substantially the same as in Fig. 1. There are four switches 51, 53, 55 and 57 and four diodes 61, 63, 65 and 67. However in this instance two coupled inductors 82 and 84 are used. This allows implementation with a single magnetic device.

Coupled inductors are devices with more than one winding on a single magnetic core. Magnetic energy stored by establishing a current in one winding can be released by allowing a current to start flowing in another winding. The dots indicate the winding sense and it is the relative placement of these which is significant to the operation of the circuit. The charge goes to the lowest voltage complementary battery. If, for example, battery 87 has the highest voltage, switch 57 closes. Current entering the dot of inductor 84 would continue to flow to battery 85 after switch 57 is opened. However if the voltage of battery 81 had been lower than that of battery 85, then opening of switch 57 would cause current in inductor 84 to be replaced by a current entering the dot of coupled inductor 82 and charging battery 81. If the ideal transfer should have been from battery 87 to battery 83, a subsequent step, namely closing switch 51, would be required.

Fig. 3 shows a modified version of the device shown in Fig. 2. The switches, diodes and batteries have the same number as in Fig. 2 with the addition of ".1". Here each coupled

inductor 86 and 88 has two sets of windings. The set of windings with the highest number of turns is connected to the switch string. The set with the lower number of turns is connected to the diode string. The effect of this is that the charging pulses can be made high compared to the discharge pulse. Reversing the turns ratio results in high discharge and low charge pulses. The use of pulsed currents in this way may increase the life of the battery by destroying internal leakage paths between plates. High current pulses can break these paths.

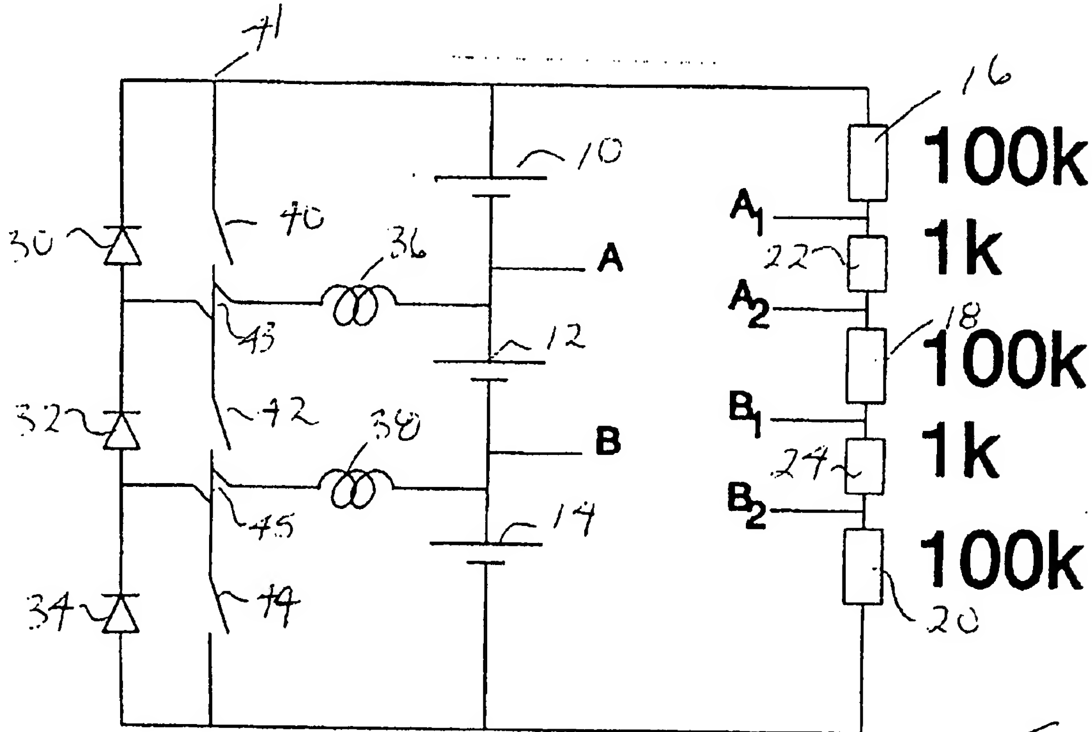
Fig. 4 is a pulsing circuit similar to that in Fig. 2, but adapted for a single cell or battery 90. Pulses of charge are taken out of the battery and then put back into the battery which increases its life. There is a coupled inductor 95 in series with diode 97 and another coupled inductor 91 in series with switch 93. Inductor 91 has a large number of turns. The current ramps up at a low rate when the switch is closed. When the switch opens a high current flows through the diode and inductor 95 which has a relatively low number of turns. This current ramps down quickly.

Referring back to Fig. 1, the device can be analyzed to show when a particular battery is weak. For example, if battery 14 becomes weak then switches 40 and 42 operate but not switch 44. Additional counters can be used to count the individual switch pulses and check the counter values periodically.

It will be understood by someone skilled in the art that many of the details provided above are by way of example only and are not intended to limit the scope of the invention.

WHAT IS CLAIMED IS:

1. A battery equalizer substantially as described herein.



100k
1k
100k
1k
100k
16
18
20
22
24
A1
A2
B1
B2
A
B
10
12
14
36
38
40
41
42
43
44
45
30
32
34


Fig. 1

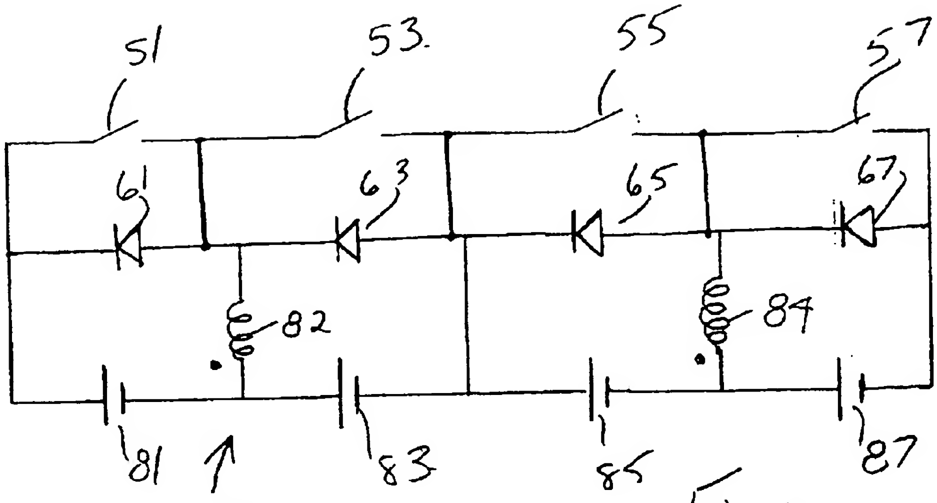



Fig. 2

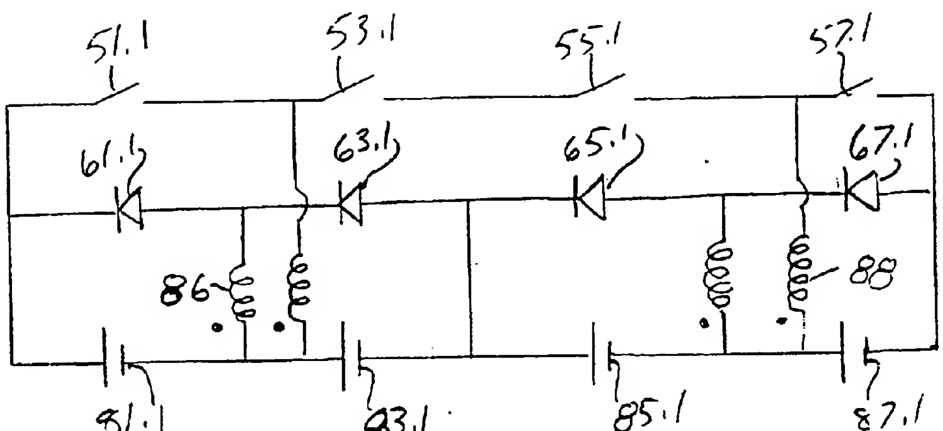



Fig 3

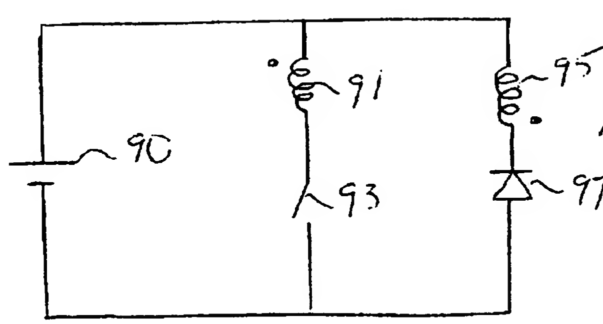



Fig. 4

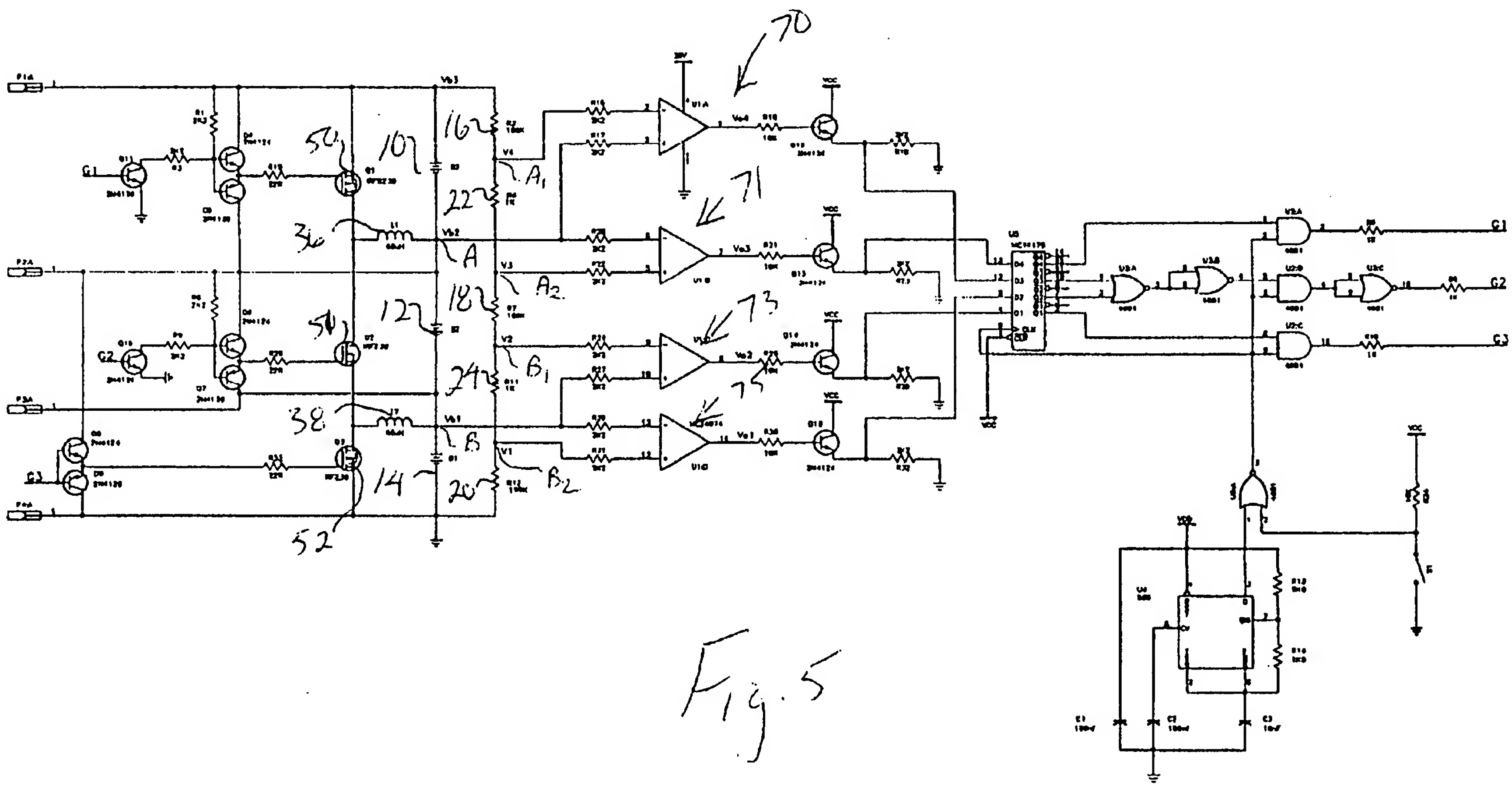



Fig. 5

| Title | BATTERY EQUALIZATION CIRCUIT | |
|---|---|---|
| Size C | Number | Rev 4 |
| Date MAY 2, 1994 | | Drawn by LMW |
| Filename EQULBAT3.S01 | | Sheet 1 of 1 |

## Equalization 94-12-05

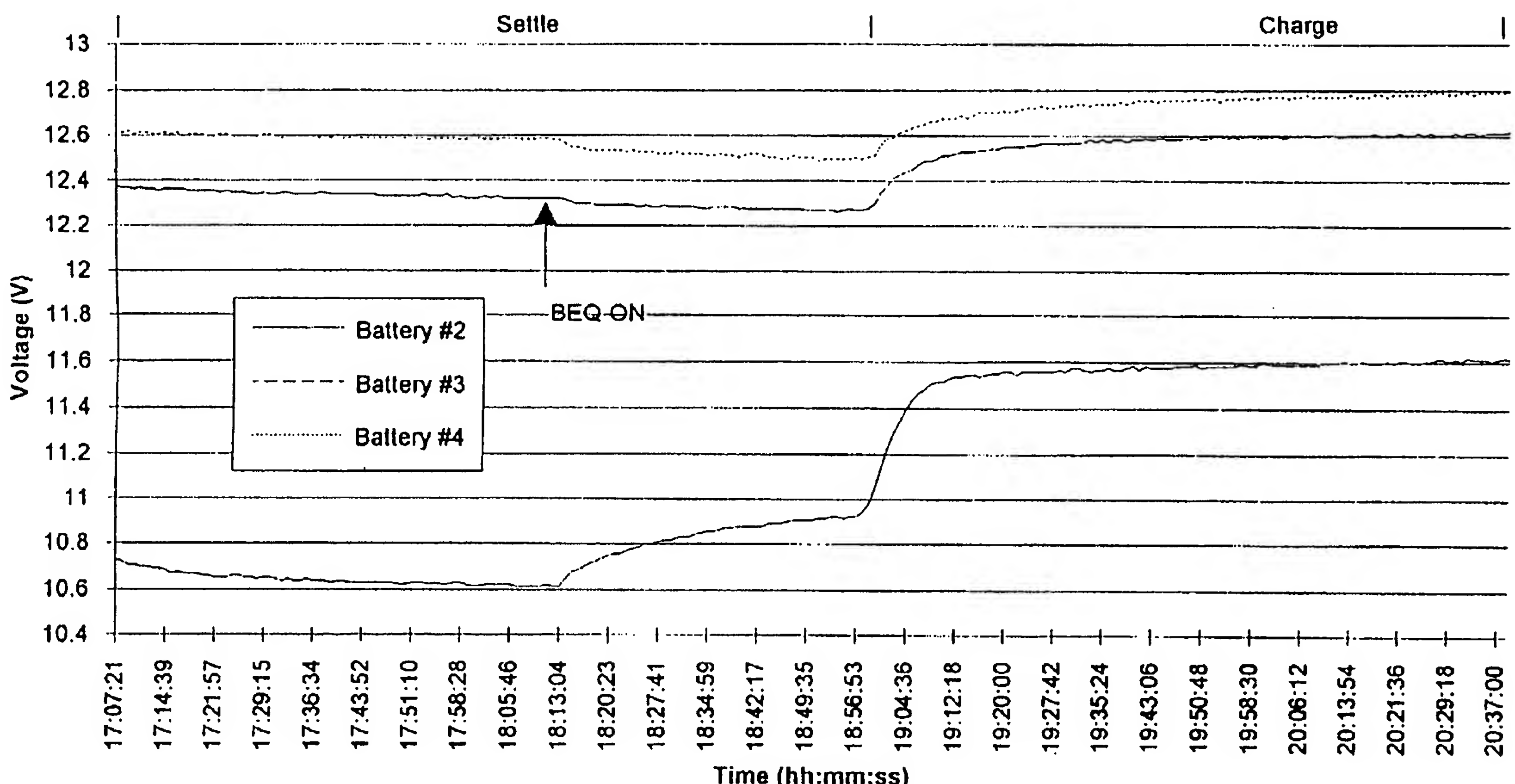



Fig 6